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Journal of Dental Specialities

Journal homepage: https://www.jdsits.in/

Review Article

3D analysis of effects of MARPE on skeletal, dental and airway structures – A systematic review

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Abstract

Background: MARPE represents a non-surgical approach to treating transverse maxillary deficiency. Nevertheless, the available evidence regarding the effectiveness of MARPE is limited.
Objectives: This systematic review aims to evaluate the efficacy of MARPE on factors such as skeletal and dental transverse maxillary dimensions, success rate, maxillary sinus width, upper airway dimension, effects on obstructive sleep apnea and periodontium.
Materials and Methods: Four electronic databases were searched: PubMed, SCOPUS, Science Direct and COCHRANE with Publication date restriction from 2000 to till date.
Selection criteria: observational studies, non- randomized and randomized clinical trials done on patients aged up to 25 years with transverse maxillary deficiency, undergoing treatment with MARPE were considered.
Data collection and analysis: Inclusion eligibility screening, data extraction, and assessment of risk of bias were conducted independently.
Results: A total of seven articles were included in the study. MARPE showed a high success rate ranging from 83.9-100%, with significant skeletal transverse width increase (1.04- 3.37 mm) and intermolar dental width increase (2.85- 6.7 mm). A significant increase in the airway dimensions and apnea/hypopnea index was present ($p<0.05$). A significant decrease in the maxillary sinus width (- 2.11 ± 0.72 mm) and the buccal plate thickness by 0.6 mm could be observed.
Conclusion: MARPE has a high success rate as a treatment method in skeletal and dental expansion. As some amount of bias is associated with the studies selected further research involving superior quality is recommended.

Keywords: MARPE, Maxillary expansion, RME

Received: 06-02-2025; **Accepted:** 20-08-2025; **Available Online**: 29-06-2025

1. Introduction

Transverse maxillary deficiency, a condition that is notably present among individuals seeking orthodontic treatment, may be observed in as much as 23.3% of the primary dentition population.[1] This particular malocclusion tends to emerge during the growth and development of the face. If not intervened upon, it is likely to influence the permanent dentition, given the low probability of spontaneous correction.[2]

Maxillary transverse deficiency, whether accompanied by posterior crossbite or not, can lead to various challenges for the patient. These may include varying degrees of occlusal disharmony, alterations in tongue posture, potential harm to periodontal structures such as local bone loss and gingival recession, functional shifts in the mandible due to improper buccolingual tipping of posterior teeth, asymmetric mandibular positioning in growing patients, joint disorders, muscle function disturbances, and insufficient space in the dental arch for proper dental alignment.[3-5] However, a serious implication of maxillary transverse deficiency is the

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https://doi.org/10.18231/j.jds.15842.1759123468

subsequent constriction of the nasal cavity, raising the nasal air resistance and could potentially contribute as an etiological factor to obstructive sleep apnea syndrome.[6,7]

The use of tooth-borne expanders within Rapid Palatal Expansion (RPE) has proven effective in treating individuals with maxillary transverse deficiency.[8,9] As patients undergo growth, there is a gradual process of calcification and interdigitation of craniofacial sutures, including the midpalatal suture and performing Rapid Palatal Expansion (RPE) becomes more challenging due to heightened mechanical resistance from these structures.[10,11] Therefore, Side effects including bone dehiscence or fenestration, gingival recession, root resorption, posterior teeth buccal tipping, and relapse are more common as the skeletal expansion decreases.[12,13] Bishara and Staley[8] reported that the most favorable age for tooth-borne maxillary expansion is before 13–15 years, as outcomes become less predictable and less stable in older patients.

Surgically-assisted rapid palatal expansion (SARPE) is often indicated to the older patients with transverse maxillary deficiencies. This procedure increases expansion predictability and success, and reduces its side effects.[14] SARPE technique involves a LeFort I osteotomy combined with the surgical rupture of the midpalatal suture reducing the mechanical resistance to lateral forces applied by Hyrax expanders, typically anchored to the first molars and first premolars. Despite its advantages, SARPE raises both biological and financial costs of treatment. The procedure necessitates hospitalization and general anesthesia, potentially discouraging patients from opting for surgical-orthodontic treatment.[15]

As a result, some authors have explored the use of orthodontic micro implants as supplementary anchorage devices to enhance the application of mechanical forces to circum-maxillary sutures, eliminating the necessity for otherwise essential osteotomies.[16] This system, known as micro-implant-assisted rapid palatal expansion (MARPE), directs forces towards the micro-implants rather than applying pressure to the teeth or periodontium. Its design aims to optimize skeletal effects while minimizing dentoalveolar effects during expansion.[17] MARPE has received wide spread attention in recent years and several researchers have studied the efficacy of MARPE. However, to our knowledge, a systematic review on many factors influencing MARPE and its results on various anatomical structures has not yet been published.

This review aims to investigate the efficacy of MARPE by assessing various outcomes such as: achieved skeletal and dental expansion, upper airway expansion, maxillary sinus width, effects of MARPE on obstructive sleep `apnea and the periodontium.

2. Materials and Methods

2.1. Protocol and registration

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, this systematic review adheres to established reporting standards.[18] The review protocol was registered with PROSPERO under the unique registration number CRD42024516523. Further information about the protocol can be accessed at https://www.crd.york.ac.uk/

2.2. Eligibility criteria

In accordance with the study objectives, studies involving adolescents and adults aged upto 25 years with transverse maxillary deficiency, undergoing treatment with RPE and MARPE, including all variations of MARPE appliance designs, whether hybrid tooth-bone-borne or solely bone-borne, as well as all types of expansion protocols were considered. However, Eligible studies needed to report on the outcomes such as skeletal and dental expansion, upper airway expansion, maxillary sinus width, effects of MARPE on obstructive sleep apnea and periodontium.

Both randomized and non-randomized clinical trials and observational studies, whether prospective or retrospective, were considered eligible for inclusion in the review. Exclusion criteria comprised studies involving individuals with cleft lip and palate or craniofacial anomalies, those with a history of maxillofacial surgery, and in vitro simulations such as Finite Element Method (FEM) analyses.

2.3. Information sources and search strategy

A comprehensive search strategy was formulated in collaboration with an experienced post graduate teacher from Public health Dentistry department. For the selection of search terms, PICOS questions were made which included MARPE in orthodontics, MARPE in young adults, palatal expansion, non-surgical techniques, study designs incorporated were case control studies, cohort studies, non-randomized control trials and randomized control trials. Four electronic databases were searched: PUBMED, SCOPUS, Science Direct and COCHRANE. Same search terms were used for all data bases. Language restriction with only English was applied. Publication date restriction from 2000 to till date was considered. Detailed PRISMA flow chart and search strategy are attached in **Figure 1** and **Table 1** respectively.

2.4. Study selection

Three investigators were involved in the study selection process (S.P, P.D, S.P). The selection process was carried out using Rayyan (a web-based software platform that helps in protocol development, import and export of searched articles and duplicate removal, thereby helping in streamlining the production of high-quality systematic reviews). After removal of duplicates, each retrieved record was assessed by

two independent observers based on predefined eligibility criteria. All articles full texts were thoroughly studied and evaluated.

2.5. Data items and collection

Data extraction was conducted independently by two researchers (S.P, P.D). Any differences between the opinion of two researchers were discussed and dissolved. The extracted data was further evaluated by another researcher (S.P) for confirmation.

2.6. Risk of bias assessment in individual studies

JBI critical appraisal tool for assessment of risk of bias for cohort, cases control and for randomized control trials was used. The assessment is tabulated and attached.

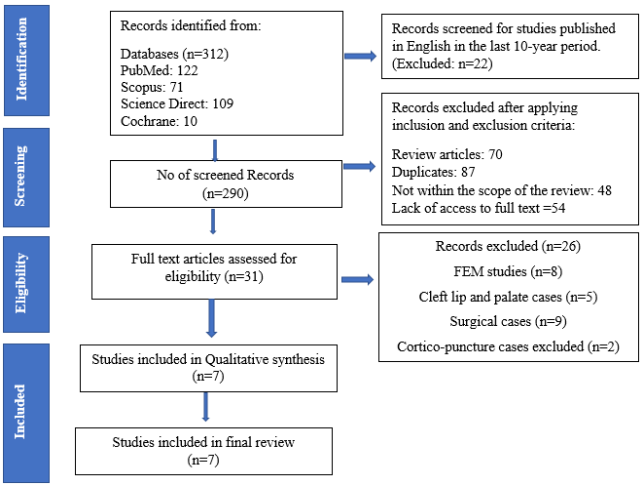

Figure 1: PRISMA Flow chart

3. Results

3.1. Success rate of MARPE

Three articles out of the total seven reported the success rate of MARPE which ranged from 83.9% - 100%. Only one study reported the success rate of MARPE as 100%

Table 1: Search strategy

Database	Date of last search	Filters applied	Keywords
Pubmed	11-02-2024	Case reports, case series, clinical studies, RCTs, English, articles published in last 10 years, free full text.	Marpe or mini implant or assisted or rapid maxillary expansion or orthodontics
Scopus	11-02-2024	Case reports, case series, clinical studies, RCTs, English, articles published in last 10 years, free full text.	Marpe or mini implant or assisted or rapid maxillary expansion or orthodontics
Cochrane Central Library	11-02-2024	Case reports, case series, clinical studies, RCTs, English, articles published in last 10 years, free full text.	Marpe or mini implant or assisted or rapid maxillary expansion or orthodontics
Science Direct	11-02-2024	Case reports, case series, clinical studies, RCTs, English, articles published in last 10 years, free full text.	Marpe or mini implant or assisted or rapid maxillary expansion or orthodontics

Table 2: JBI critical appraisal tool for assessment of risk of bias for RCT

Studies	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Choi et al. 2023[18]	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
Chun et al 2022[23]	Y	N	Y	N	N	N	N	Y	Y	Y	Y	Y	Y
Aneris et al 2023[19]	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y
Jia et al 2021[24]	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y
Brunetto et al, 2022[26]	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y

Table 3: JBI critical appraisal tool for assessment of risk of bias for cohort studies

Studies	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Vo et al 2021[22]	Y	Y	Y	N	Y	Y	Y	Y	Y

Table 4: JBI critical appraisal tool for assessment of risk of bias for case control studies

Studies	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Mehta et al 2022[20]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

3.2. Skeletal transverse maxillary expansion

Five articles have reported the skeletal transverse maxillary expansion. A variety of measurements were used for the assessment of skeletal transverse expansion. Nasal width, nasal base width, mid palatal suture separation, inter processus zygomaticus width, frontozygomatic suture–FZS, zygomaticomaxillary suture–ZMS, nasopalatine foramen–NPF, greater palatine foramen–GPF, maxillary basal bone width were the different measurements used across the studies. The mean skeletal expansion was statistically significant in all the five articles. Only one study reported the skeletal to dental expansion ratio of MARPE of about 61.4%

3.3. Dental transverse maxillary expansion

Dental transverse maxillary expansion was reported in five articles. A variety of measurements using the intermolar widths (IMW) and inter-canine (ICW) widths were used across these studies. The mean ICW ranged from 1.78-3.70 mm, mean interdental width at the premolar area ranged from 6.1-6.3 mm and the mean IMW ranged from 2.85- 6.7 mm. Measurements in all the studies were statistically significant.

3.4. Maxillary sinus width

Only one article reported the maxillary sinus width in the RPE.[23] An increase in nasal width decreased maxillary sinus width with a mean reduction of - 2.11 ± 0.72 mm. This cha0nge was statistically significant.

3.5. Upper airway dimension

One article studies the effects of MARPE on retropalatal and retroglossal airway dimensions and minimal transverse constriction.[20] Volumetric measurement of the upper airway segments was carried out. There was a statistically significant increase for all volumetric parameters and minimal transverse airway constriction ($P < 0.05$) between the pre- and post -expansion periods.

3.6. Effect on obstructive sleep apnea

Only one of the five articles, studies the effects of MARPE on obstructive sleep apnea in adults.[22] Statistically significant improvements on the apnea/hypopnea index (65.3%), mean oxygen saturation, snoring duration, and bruxism to apnea index could be observed.

3.7. Periodontal effects

Only one article studied the periodontal effects of MARPE on bone.[24] The buccal and palatal bone plate thickness were measured at the premolar and molar areas for the assessment of the periodontal effects of MARPE. There was a decrease in the mean buccal plate thickness by 0.6 mm and the value was statistically significant.

Table 5:

Author Year & country	Study design	Sample size, sex, age (range, mean ± SD	Data collection	Intervention: appliance type, location, tads	Intervention: expansion protocol	Outcome
Choi et al. 2023, south korea[18]	Randomized clinical trial	Total N= 36 Included N= 31 12f, 19m 19-35 years 23.6 ±4.4	CBCT Images at T1 – pre - treatment T2- immediately after removal of appliance	modified Hyrax-type expander (HyraxII; Dentaurum, Ispringen, Germany) N=4 TADS (diameter, 1.5 mm; self-drilled type; BMK, Biomaterials Korea, Seoul, Republic of Korea; L= anterior -6 or 13mm, posterior – 8 or11 mm	0.2 mm activation per day. Retention phase of 3 months following active expansion	Skeletal linear measurements Interalare width, Interprocessus zygomaticus width Dentoalveolar linear measurements Interectocanine width, Interectomolare width, Interfurcation width, Intercentral fossa width Dental angular measurements Right first molar, right first premolar, Left first molar, Left first premolar The success rate of the midpalatal suture separation and the stability of the miniscrews at the time of the MARPE removal were considered secondary outcomes

Aneris et al.20923. Brazil[19]	Randomized clinical trial	Total N= 187 Included= 20 4m, 16f 18 years or older 24.5 ± 6.2 years	CBCT images at T0- pretreatment T1- after 120 days post expansion	MARPE type appliances with expander screws (PecLab Belo Horizonte, MG, Brazil) N=4 TADS used	Retention phase for 120 days following active expansion	airway volumes for the total upper, retropalatal, and retroglossal airways, minimal transverse airway constriction
Mehta et al. 2022. USA[20]	Retrospective study	Total N= 60 11-15 years 13.69 ± 1.74 years	CBCT images at T1- pretreatment T2- post expansion T3- post treatment	MARPE appliance N= 2 TADS L= 12mm D= 1.5mm, Straumann GBR System, Andover, Mass; a tooth-borne expander anchored to the molars and premolars	two turns per day (0.25 mm per turn, 0.5 mm per day	Nasal height (NH), nasal length (NL), nasion–ANS height (NAH), ANS–PNS length (APL), pyriform height (PH), and nasal septal deviation angle (NSDA), alar width (AW), alar base width (ABW), anterior nasal cavity width (ANCW), posterior nasal cavity width (PNCW), maxillary intermolar width (IMW), and maxillary intercanine width (ICW)
Brunetto et al. 2022. Brazil[21]	Randomized clinical trail	N=32 18 years or above	CBCT images at T1= pretreatment T2- immediately after last expansion	MSE expander N= 4 TADS L= 9, 11, 13 mm D= 1.5 mm	0.5–1 mm per day until the interincisal diastema appears, and after that 0.25–0.5 mm per day, Retention phase of 3 months following active expansion	Epworth Sleepiness Scale (EES) and Quebec Sleep Questionnaire (QSQ), and home sleep testing (HST)
Vo et al. 2021. Vietnam[22]	Prospective study	N=30 6-16 years	CBCT images at T1 – pre-treatment T2 – after one month of maxillary expansion	a Hyrax-type RPE -Rapid palatal expander	Activation for one month, the mean extensibility of the RME screw -7,25 ± 1,40 mm	Maxillary and mandibular arch widths at the positions of canines (C-3), first premolars (D-4), and first molars (6- 6). IMW: Inter Molar Width, DP: Depth of the palate, NW: Nasal width, NFW: Nasal floor width, Maxillary sinus width (MSW), ossification degree of the mid-palatal suture
Chun et al. 2022. South Korea[23]	Randomized clinical trial	Total N= 51 Included N= 40 14m, 26f 7-25 years 14±4.2 years	CBCT images at T0- pretreatment T1- immediately after expansion T2- after 3month consolidation	Tooth-borne RPE- Hyrax expander (Dentaurum, Ispringen, Germany) with bands on first premolars and molars and MARPE- hyrax screw with N=4 TADS L – 7or 9 mm D- 1.8 mm	One-quarter of a turn (0.20 mm/turn), activated 35 times, which corresponded to 7.0 mm of hyrax screw expansion. After active expansion, a retention phase of months was followed	Skeletal (frontozygomatic suture–FZS, zygomaticomaxillary suture–ZMS, nasal width–NW, nasopalatine foramen–NPF, greater palatine foramen–GPF, and midpalatal suture–MPS), dentoalveolar (maxillary width–MW, interdental width–IDW,

						and dental inclination–DI), and periodontal measurements (buccal bone plate thickness – BBPT; and palatal bone plate thickness – PBPT
Jia et al. 2021 China[24]	Randomized clinical Trial	N= 60 21m, 39f 12-18 years 15.1 ± 1.6	CBCT images at T1- before expansion and T2- one week after expansion	MARPE appliance-jackscrew, four tubes, and two bands on the upper first molars. The jackscrew (length: 12 mm; anatomic expander type: "s;" Forestadent, Pforzheim, Germany) Four custom stainless-steel tubes (internal diameter: 2.0 mm; external diameter: 3.0 mm; length: 3.0 mm). N=4 TADS L-12mm, D- 1.7 mm	Two-quarter turns (1808, 0.5 mm) per day and 3 months of retention.	Skeletal- NW Nasal width, MBBW Maxillary basal bone width; SE Suture expansion of midpalatal suture. SE_ANS Suture expansion at ANS, SE_PNS Suture expansion at PNS Alveolar- MAW Maxillary alveolar width AH Alveolar height Dental- IAW Inter-Apex Width, ICW Inter-Crown Width, TI_M1 Tooth inclination of first molars, TI_P1 Tooth inclination of first premolars Appliance AE Appliance expansion

4. Discussion

The aim of the present systematic review was to assess the various effects of MARPE in adolescents and young adults aged upto 25 years. A total of seven studies have met the eligibility criteria and were included in the review after the assessment of the risk of bias.[19-25] While there were slight variations in the definition of successful expansion among the included studies, a common consensus considered expansion satisfactory when the occlusal aspect of the lingual cusp of the maxillary first molars came into contact with the occlusal aspect of the buccal cusp of the mandibular first molars.[26] The success rate of MARPE ranging from 83.9%-100% was reported in three out of the seven articles considered in the systematic review. However only one study reported the success rate of 100%.

Skeletal transverse maxillary expansion was reported by five articles. Considerable variation existed among the measurements used across these studies for the assessment of transverse skeletal expansion. Nasal width, nasal base width, mid palatal suture separation, inter processus zygomaticus width, frontozygomatic suture–FZS, zygomaticomaxillary suture–ZMS, nasopalatine foramen–NPF, greater palatine foramen–GPF, maxillary basal bone width were the different measurements used across the studies. The mean skeletal transverse expansion ranged from 1.04- 3.37 mm considering the nasal width across all the five articles. The values are statistically significant in all the studies but are not clinically different from the mean skeletal expansion of 3.3 mm produced by SARPE.[27]

Dental transverse maxillary expansion was reported in five out of seven articles. Slices of CBCT images and volumetric CBCT images were used for the measurements of the widths. Only one article has used dental casts for the measurements of the widths. These articles found that the mean increase in the ICW and IMW ranged from 1.78- 3.70 mm and 2.85- 6.7 mm respectively. In contrast, SARPE demonstrated a statistically larger mean increase in intermolar width (MD: 7.0 mm, 95% CI: 6.1 mm–7.8 mm) compared to MARPE, although the clinical difference was not significant.[27] Only one study provided information on the ratio of skeletal to dental expansion achieved through MARPE, indicating a notable proportion of approximately 61.4%.

From the other outcome measures, an article by Vo et al.[23] reported the maxillary sinus width after the rapid palatal expansion. Maxillary sinus width (MSW) was the width of the maxillary sinus on the extension of the nasal width. An augmentation in nasal width was associated with a concurrent reduction in maxillary sinus width, demonstrating a statistically significant mean decrease of -2.11 ± 0.72 mm ($p < 0.05$) which is comparable to the previous study reporting -1.45 ± 1.77 mm reduction in the maxillary sinus width.[28]

The effects of MARPE on upper airway dimensions was reported in one article by Aneris et al.[20] This study reported

the effects of MARPE on the total, retropalatal, retroglossal airway dimensions and minimal transverse constriction. In this study, it was evidenced that MARPE therapy led to a significant enhancement in volumetric parameters within the upper airway spaces. Specifically, the upper airway volume exhibited an average increase of approximately 14%. This outcome is consistent with the results of a prior study that documented a rise in nasopharyngeal volume of around 8.48%.[29] This finding illustrates a similarity in the secondary response of MARPE to the outcomes observed in both conventional RME in children and surgically assisted RME in adults.[30-32]

The effects of MARPE on obstructive sleep apnea was reported in one study by brunetto et al.[22] Epworth Sleepiness Scale (ESS) and Quebec Sleep Questionnaire (QSQ); Home Sleep Test (HST); Cone Beam Computed Tomography (CBCT) were some of the examinations used across this study. The intervention group exhibited a statistically significant average reduction of 65.3% in the Apnea-Hypopnea Index (AHI). However, a study by Vinha et al. discovered a 56% average reduction in the Apnea-Hypopnea Index (AHI) among SARPE patients who underwent Le Fort I and mid-palatal osteotomies.[33] In a recent study, Liu et al. identified an average reduction of 54% in the Apnea-Hypopnea Index (AHI) among 20 non-obese adult patients who underwent maxillary distraction osteogenesis.[34] Therefore, MARPE demonstrated to be a successful alternative treatment modality for the obstructive sleep apnea as compared to SARPE and Distraction osteogenesis.

Only one study by chun et al.[23] has reported the periodontal effects of MARPE by measuring the buccal bone plate thickness (BBPT) and palatal bone plate thickness (PBPT) at the premolar and molar regions. Following RPE and MARPE expansion, there was an observed mean decrease in buccal bone thickness of the first molars by 0.6 mm with the measurements ranging approximately from 0.4–0.7 mm. In contrast, palatal bone thickness exhibited an increase of 0.5–0.9 mm immediately after the expansion procedures. These findings suggest a buccal displacement of the anchor teeth within the alveolar bone. The BBPT was reduced significantly in the molar area in the RPE group as compared to the MARPE group in the consolidation phase. This suggests that, for a given amount of expansion, the MARPE group experiences a reduced buccal displacement of the anchor teeth within the alveolar bone compared to other groups. These results are consistent with the study done by Garib et al. which documented that RPE resulted in buccal bone dehiscences, particularly on the anchorage teeth, especially in individuals with thinner buccal bone plates.[34]

5. Conclusion

This review concluds that MARPE has a higher success rate (83.9-100%) in skeletal (1.04- 3.37 mm) as well as dental expansion (2.85- 6.7 mm). These results have no significant differences from the expansion achieved by SARPE. Furthermore, it has been demonstrated that MARPE has led to a significant increase in the retroglossal, retropalatal airway dimensions and apnea/hypopnea index. However, there exists a scarcity of evidence indicating that MARPE may affect the dental and periodontal tissues by causing decrease in the buccal plate thickness.

Given the substantial risk of bias observed in most of the studies included, it is crucial to interpret the data with caution. Conducting randomized clinical trials and prospective cohort studies is recommended to further enhance evidence on MARPE sefficacy.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Cite this article: Ponnada SR, Pattanaik S, Dittakavi P, Gandikota C, Nanda SB. 3D analysis of effects of MARPE on skeletal, dental and airway structures – A systematic review. *J Dent Spec*. 2025;13(2):177-184.